Quantification of EMG Signal for Foot Flexion using Frequency Domain Anaysis

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ABSTRACT
There are several methods available for EMG(Electromyography) based user intent detection, wherein muscle activation has been recognized by different approaches.Even thoughEMG detection and processing has been done by many other researchers, need of improved model is still rising. The notion of this study is to propound a novel approach whereby quantification of EMG signal for foot flexion can be done. Signal processing and data analysis, played substantial role in that, thus present study had used contemporary frequency analysis methodology. The Biopac's software tool, Acqknowledge, was explored for the purpose and the results obtained were quite precise. Further to increase its reliability, analysis was performed over data samples of more than 10 subjects.

Keywords
EMG(Electromyography), Frequency analysis, Foot flexion, Mean Frequency, Muscle activation**.**

1. INTRODUCTION
The human body is composed of various types of cells fundamental for the life. One of these is the myocyte, found in muscle tissues present in most of the living beings. These tissues have the ability to extend or contract based upon the neural stimuli they receive from the brain. Muscle tissues perform both the functions i.e. involuntary movement of internal body organs and voluntary production of external force or motion. They are responsible for hand movement and grasping, postural control as well as locomotion. Three types of muscle tissues are identified in humans named: cardiac muscle, smooth muscle and skeletal muscle.

The skeletal muscle tissue is attached to the bone and is the one supplied with neuronal impulses to generate contractions responsible for skeletal movement. These are the only type of muscle that come under voluntary control and hence used for movement detection and processing. In response to the stimulus from neurons, the muscle fibers depolarize and hence generate electrical potential around the corresponding muscle. It is sometimes also termed as muscle action potential. Electromyography is the process by which these muscle action potentials are measured.

The development of EMG started as early as 1666 when Francesco Redi's documented the electricity generation by the specialized muscle of the electric ray fish. As the research progressed, Dubios-Raymond discovered the possibility of recording electrical activity during a voluntary muscle contraction in 1849 but the actual acquisition was not done until the end of 19th century. Marey in 1890 introduced the term electromyography abbreviated EMG now a days. It is a non-invasive procedure of electrical stimulus estimation corresponding to the event detection in human body. Clinical use of surface EMG (sEMG) for the treatment of more specific disorders began in the 1960s [1]. EMG records the combination of the muscle fiber action potentials from all the muscle fibers of a single motor unit using skin surface electrodes (non-invasive) placed near this field. Individual muscle fiber action potentials can also be acquired using needle electrodes placed directly in the muscle but it is an invasive procedure. Hence surface electromyography is increasingly used for recording from superficial muscles in clinical as well as experimentation protocols [2].

The application area of EMG is vast. It is used in diagnosis of neuromuscular diseases [3], kinesiology [4], low back pain [5], essential tremor assessment [6] and motor control inabilities, intramuscular activities under clinical applications. EMG signals are used in the development of evolvable hardware chips used in prosthetic hands [7]. Furthermore EMG is applied for the measurement of isometric muscle movement (type of muscle activity that does not involve any muscle contractions) for integrating other electronic devices [8]. Interactive software gaming, for example, *'Muscleman'* is another interesting application based on bio-signal interface [9]. Owing to the aforementioned utilities, this paper presents the basic data acquisition and analysis procedure for surface EMG using the Biopac's MP 150 system. The most frequently analyzed parameter are suggested in this paper with the results obtained by processing of muscle activation signals obtained from participating individuals in the study. Section II describes the experimental paradigm for trials. Resulting parameters are analysed and discussed in section III. Finally section IV concludes the paper.

2. MATERIALS AND METHODS

2.1 Recruitment
A total of five subjects (all males) aged between 18-25 years participated in the study with verbal consent. All the participants were healthy with no visible atrophy in the lower limb muscles. They were not on any medication during the experimentation period.

2.2 Experimental paradigm
The muscle investigation of the lower limb is done by using the anatomical landmark system. Muscles were further classified by plantar flexion and dorsi flexion (foot) movements.

Plantar flexion defines the muscle movement for pointing the foot downward (away from the leg) whereas Dorsi flexion refers to upward foot movement (towards the leg). The superficial muscles responsible for the actions and used in this

paper were Gastrocnemius (GC), FibularisLongus (also known as Peroneus Longus, FL), Tibialis Anterior (TA), HalluciusLongus(HL). The GEL-102 conductive gel was used for better conduction of the EMG signal from the muscles.

2.3 Data Acquisition Protocol:

Data was acquired from the dominant side (right leg for all of the participants) by BIOPAC MP150 system using shielded 4mm electrode pairs (EL 254s) compatible with BIOPAC DAQ system. Fig. 1 shows the electrodes attached over the selected muscles with reference to the ground (ankle bone) over the leg of one of the participant. The electrodes were gently pushed at the sites and fixed with the help of micro pore adhesive tape.

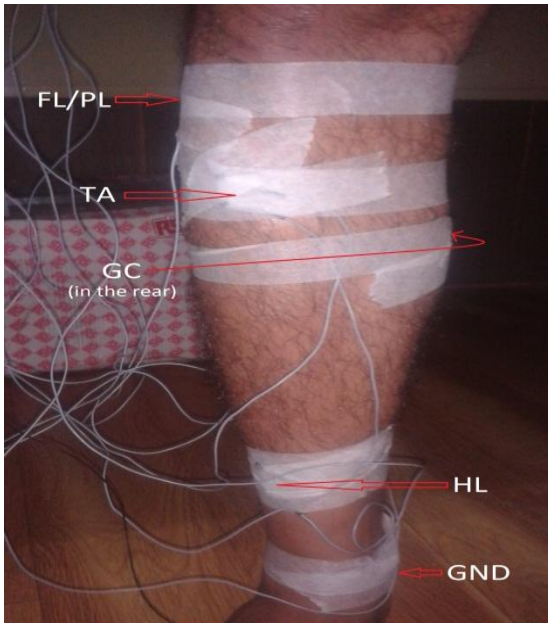

Fig 1: EMG electrode placement

The baseline with no muscle movement is recorded at first, in both sitting and standing states. Participants were asked to plantarflex and dorsiflex the foot repetitively for five trials in sitting state. While standing, the data is recorded while performing heel-off and toe-off actions, hence plantar and dorsi flexion of foot. The same is repeated with every participant.

3. RESULTS AND DISCUSSIONS

3.1 Signal check and quality

The baseline was recorded to check and compare the signal quality. And any baseline shift was removed by de-trending the signal. Rectify and mean approach was replaced by RMS (root mean square) for the smoothing. The envelope signal obtained after RMSis equivalent to the rectified form of the original signal (Fig. 2).

Another pre-processing step included the filtering of raw EMG between 10Hz to 500 Hz to remove external noise effects by appropriate setting of Biopac's modules. To enhance the signal to noise ratio proper skin preparation and electrode placement is done. The pre-processed raw data obtained from the participants for both plantar flexion and dorsi flexion movements is shown in graphical form in Fig. 3.

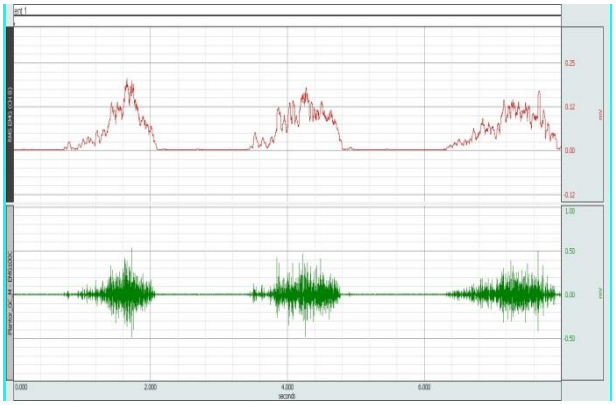

Fig 2: RMS plot (top) for given plantar flexion of GC muscle (bottom)

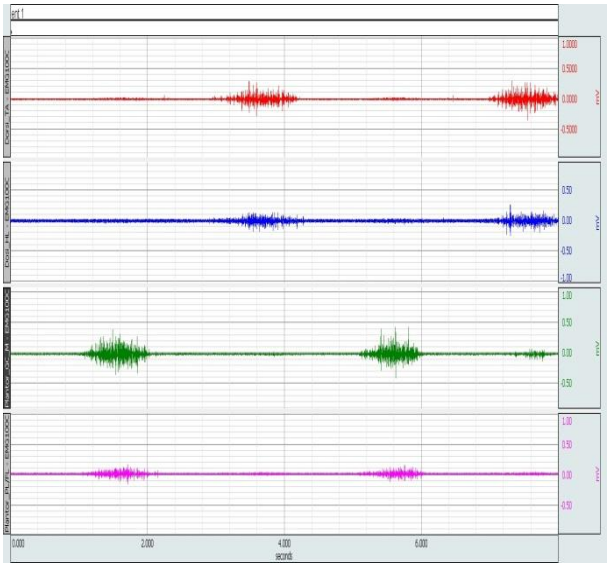

Fig 3: Pre-processed EMG signal from TA, HL, GC and FL muscles respectively during consecutive Plantar flexion and Dorsi flexion movements

3.2 Frequency analysis

To calculate and evaluate the muscle activation, the frequency analysis of the RMS envelope was done using the Biopac's signal processing tools. The values for mean frequency, median frequency and peak frequency were obtained. These parameters were extracted to find the EMG traces as standard amplitude parameters. The mathematical formulation and the obtained results are as defined below [10]:

3.2.1 Mean Frequency:

$$f_{mean} = \sum_{i=1}^{L} f_i P_i \Big/ \sum_{i=1}^{L} P_i$$

Here f_i is the frequency at a power P_i of EMG with L denoting the total number of samples. It is an average frequency, calculated as the sum of product of the EMG power spectrum and the frequency divided by the total sum of the power spectrum. The mean provides the average epochs in a data sample. Its magnitude denotes the gross innervation of the input of the selected muscle.

Table 1. Frequency analysis parameters for Dorsi flexion

Epoch	MedianF	MeanF	PeakF
1	7.75193	42.63565	7.75193
2	11.6279	46.51162	15.50387
3	11.6279	50.38759	7.75193
4	3.87596	27.13178	3.87596
5	11.6279	46.51162	15.50387
6	11.6279	62.0155	7.75193
7	11.6279	34.88372	11.6279
8	11.6279	42.63565	11.6279
9	11.6279	46.51162	15.50387
10	7.75193	19.37984	7.75193

Table 2.Frequency analysis parameters for Plantar flexion

Epoch	MedianF	MeanF	PeakF
1	3.87596	23.25581	23.25581
2	7.75193	58.13953	58.13953
3	3.87596	42.63565	42.63565
4	3.87596	46.51162	46.51162
5	7.75193	73.64341	73.64341
6	11.6279	73.64341	73.64341
7	7.75193	65.89147	65.89147
8	11.6279	50.38759	50.38759
9	3.87596	31.00775	31.00775
10	7.75193	62.0155	62.0155

3.2.2 Median Frequency:

$$\sum_{i=1}^{f_{median}} P_i = \sum_{i=f_{median}}^{L} P_i = \frac{1}{2}\sum_{i=1}^{L} P_i$$

As mathematically described, median frequency divides the power spectrum in two halves, hence gives the 50% of the EMG amplitude or the average of the data samples.

3.2.3 Peak Frequency:

$$f_{peak} = \max(P_i) \quad with\ i = 1, \ldots, L$$

This is the frequency at which maximum power occurs during each epoch. So it is useful for determination of maximal voluntary contraction (MVC) i.e. how well a muscle can be activated. Peak to peak data analysis which is measured in millivolts defines the amount of energy expenditure in the corresponding muscle activation.

Table I and II given above specifies these parameters in terms of their magnitude for dorsi flexion and plantar flexion movements respectively.

3.3 Location Of Muscle Activation

Location of muscle activation is important to detect the start and stop of the event during actual foot movement. Rectangular waveform as shown in Fig. 4 represents muscle activity located for the TA muscle during foot flexion of a participant. The baseline standard deviation of 2.5 is used so as to avoid false activation detection occurring due to electrode displacement or external electrical disturbances. This activation period can be used to define the muscle strength, based on duration of the muscle activation. Also the same can be used to define different gait parameters like stride lengthand gait speed of the individual.

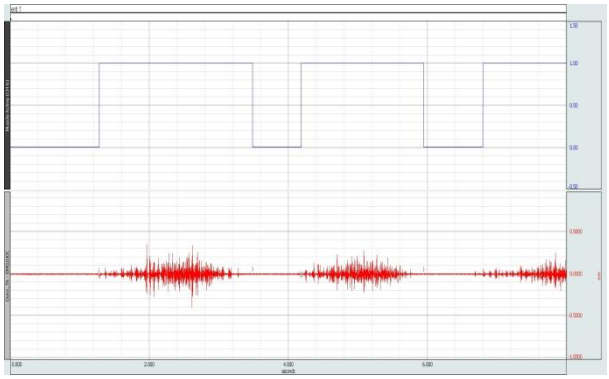

Fig 4: Activation period plot (top) of TA muscle (bottom) during Dorsi flexion

4. CONCLUSION

The EMG data is acquired and analyzed from healthy participants in the study. Biopac'sAcqknowledge software is used for its processing and it proved to be a very useful and efficient tool for detection and analysis of muscle activation in the lower limb of the human body. The result of this study shows that frequency analysis of the acquired signal can provide appropriate information for muscle activity. From the frequency plot, actual movement intention of the subjects with corresponding muscle innervations can be detected. It is also observed that for minimizing the error while acquiring the data, environmental conditions for every subject should be same.

The results obtained were precise and can be used for further analysis in synchronism with other physiological parameters such as ECG or EEG. In future, the authors intend to use the same for EEG intent detection acquisition for various lower limb muscle movements.

5. ACKNOWLEDGMENT

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